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# A Revision of the Chinese Endemic *Orychophragmus* (Brassicaceae)

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**ABSTRACT.** *Orychophragmus* consists of two species endemic to China. The new combination *O. limprichtianus* is proposed. *Cardamine hickinii* and *Alliaria grandifolia* are reduced to synonymy of *O. limprichtianus*, and *C. potentillifolia*, *O. diffusus*, and *O. taibaiensis* are reduced to synonymy of *O. violaceus*.

During the revision of the Brassicaceae for the *Flora of China*, it became quite clear that the limits of some of the Chinese species of *Alliaria* Heister ex Fabricius and *Cardamine* L. have been confused, and such taxa are more appropriately placed in *Orychophragmus*. Although *Orychophragmus* is endemic to China, Ying et al. (1993) did not include it in their work of the endemic Chinese genera. Perhaps they were influenced by Schulz (1923, 1936) who recognized two species, *O. violaceus* (L.) O. E. Schulz (China) and *O. winkleri* (Regel) O. E. Schulz (Afghanistan, Tajikistan, Turkmenistan, Uzbekistan), of which the latter was appropriately placed by Botschantsev (1966) and Hedge (1968) in *Spryginia* Popov. The latter differs from *Orychophragmus* by having the median filaments connate throughout, flattened fruits, and incumbent cotyledons. By contrast, *Orychophragmus* has all filaments free, terete or slightly 4-angled fruits, and conduplicate cotyledons.

As herein delimited, *Orychophragmus* consists of two species. One of these, *O. violaceus*, is highly variable, and several of its segregates have been recognized as distinct species. The second species, *O. limprichtianus*, was previously described as *Cardamine* or *Alliaria*, but as shown below, it belongs to *Orychophragmus* because it has conduplicate cotyledons, a feature characteristic of the tribe Brassiceae and not known in any other native Chinese species of the Brassicaceae. *Orychophragmus* was excluded by Gómez-Campo (1980) from the Brassiceae because (p. 5) it has "somewhat conduplicate cotyledons." However, we have examined the cotyledonary position in both species of the genus and found them to be typically conduplicate,

as in the vast majority of the tribe. Recent studies by Anderson and Warwick (1999), using two phylogenetically informative isozyme duplications, supported the inclusion of *Orychophragmus* in the tribe Brassiceae. The Brassiceae are a monophyletic tribe readily distinguished from the rest of the Brassicaceae by having conduplicate cotyledons and/or transversely segmented (heteroarthrocarpous) fruits (Al-Shehbaz, 1985), though such fruits are lacking in *Orychophragmus*.

Although *Orychophragmus violaceus* differs substantially from *O. limprichtianus* in flower size (see key) and in having auriculate instead of non-auriculate cauline leaves, the two species belong to the same genus because they have similar basal leaf morphology (e.g., not rosulate, long petiolate, with leafletlike lateral lobes, base often cordate, margin coarsely crenate with teeth ending in apiculae), pilose indumentum of simple trichomes, saccate lateral sepals, apiculate anthers, decurrent 2-lobed stigmas, oblong and alveolate-reticulate seeds, and conduplicate cotyledons. The differences in flower size and color probably are adaptations to different pollinators.

Perhaps one of the most interesting things is that *Orychophragmus limprichtianus* was treated as two species, one each placed in *Cardamine* of the tribe Arabideae and *Alliaria* of the Sisymbrieae (An, 1987; Cheo, 1987; Zhang, 1993). However, the appropriate generic placement of this species in *Orychophragmus* and the affiliation of the genus to the tribe Brassiceae were overlooked because these authors did not examine the cotyledonary position. In light of these findings, the genus *Orychophragmus* is revised, and detailed descriptions are provided for it and its two species.

***Orychophragmus*** Bunge, Mém. Acad. Sci. Saint Pétersbourg 2: 81. 1835. TYPE: *Orychophragmus violaceus* (L.) O. E. Schulz.

Herbs annual, biennial, or rhizomatous perennial. Trichomes absent or simple. Stems erect to

ascending. Basal leaves petiolate, not rosulate, simple or pinnatisect and with 1 to 6 leaflet-like lateral lobes on each side. Cauline leaves petiolate or sessile, not auriculate or auriculate to amplexicaul at base, entire, dentate, crenate, or serrate, sometimes with 1 to 4 lateral lobes. Racemes ebracteate, elongated in fruit. Fruiting pedicels slender or stout, divaricate to recurved. Sepals oblong or linear, erect or ascending, base of inner pair slightly to strongly saccate, margin membranous. Petals purple, lavender, or white; blade obovate to narrowly obcordate, apex rounded or emarginate; claw obscurely to strongly differentiated from blade, shorter than to as long as sepals. Stamens 6, tetradynamous; filaments dilated at base; anthers oblong or linear, apiculate at apex. Nectar glands 2; median nectaries absent; lateral nectaries semiannular or annular. Ovules 20 to 70 per ovary. Fruit dehiscent siliques, linear, terete or somewhat 4-angled, sessile or short stipitate, unsegmented; valves leathery, with an obscure or prominent midvein, glabrous or rarely hairy, smooth or torulose; replum rounded, visible; septum complete, membranous, opaque, veinless; style distinct; stigma capitate, 2-lobed, lobes free, decurrent. Seeds uniseriate, wingless, oblong, plump; seed coat alveolate-reticulate, not mucilaginous when wetted; cotyledons conduplicate.

Two species: endemic to China.

#### KEY TO THE SPECIES OF *ORYCHOPHRAGMUS*

- 1a. Cauline leaves auriculate to amplexicaul; sepals linear, erect, (6-)8-13(-16) mm long, base of lateral pair strongly saccate; petals deep purple to lavender or rarely white, (12-)16-25(-32) mm long, apex rounded, claw well differentiated and as long as sepals; anthers linear, (3-)4-6(-8) mm long; style (3-)7-30(-55) mm long . . . . . 1. *O. violaceus*
- 1b. Cauline leaves not auriculate; sepals oblong, ascending, 2-3.5 mm long, base of lateral pair slightly saccate; petals white, (6-)7-9 × 3-6 mm, apex shallowly emarginate, claw obscurely differentiated and shorter than sepals; anthers oblong, 1-1.5 mm long; style 1-3 mm long . . . . . 2. *O. limprichtianus*

**1. *Orychophragmus violaceus* (L.) O. E. Schulz, Bot. Jahrb. Syst. 54 (Beibl. 119): 56. 1916. *Brassica violacea* L., Sp. Pl. 2: 667. 1753. TYPE: China (holotype, LINN not seen).**

*Cardamine potentillifolia* H. Lévillé, Mem. Real Acad. Cienc. Art. Barcelona 12: 548. 1916. Syn. nov. TYPE: China. Jiangsu, Ton-Zouo-Ze, 12 Mar. 1863, *d'Argy s.n.* (holotype, E).

*Orychophragmus diffusus* Z. M. Tan & J. M. Xu, Acta Phytotax. Sin. 36: 547. 1998. Syn. nov. TYPE: China. Zhejiang: Yuhang, 300 m, 1 June 1995, Z. M. Tan et al. 95-16 (holotype, SZ).

*Orychophragmus taibaiensis* Z. M. Tan & B. Z. Zhao, Acta Phytotax. Sin. 36: 544. 1998. Syn. nov. TYPE: China. Shaanxi: Meixian, Mt. Taibai, 1150 m, 2 July 1995, Z. M. Tan & B. X. Zhao 95-54 (holotype, SZ).

Herbs annual or biennial, (6-)15-60(-90) cm tall. Stems erect, simple or branched at base, often branched above, straight, glabrous or sparsely to densely pilose. Basal leaves not rosulate; petiole (1-)2-8(-11) cm long; blade or terminal leaf lobe cordate, reniform, broadly ovate, or suborbicular, (0.4-)1.5-10(-14) × (0.3-)1-4(-7) cm, glabrous or pilose, base cordate or rarely obtuse, margin coarsely crenate with teeth ending in apiculae, apex acute to obtuse; lateral lobes 1 to 6 on each side, sessile or petiolulate, to 3 × 2 cm, sometimes absent. Uppermost stem leaves auriculate to amplexicaul, sessile or petiolate, (0.5-)2-9(-15) × (0.2-)1-6(-9) cm, margin coarsely and irregularly dentate, rarely entire, apex acute to acuminate; auricles to 3 × 4 cm; lateral lobes absent or 1 to 4 on each side, sessile or petiolulate. Fruiting pedicels divaricate, glabrous or pilose, narrower than fruit, (0.6-)0.8-2(-3) cm long. Sepals linear, erect, connivent, (0.6-)0.8-1.3(-1.6) cm × 1.5-2.5 mm, base of lateral pair strongly saccate. Petals deep purple to lavender or rarely white, broadly obovate, (1.2-)1.6-2.5(-3.2) cm × (4-)5-9(-11) mm, apex rounded; claw as long as sepals. Filaments white to purple, erect, 0.8-1.8 cm long; anthers linear, (3-)4-6(-8) mm long, distinctly apiculate. Ovules (20 to)40 to 70 per ovary. Fruits narrowly linear, stout, terete or somewhat 4-angled, (3-)4.5-11(-13) cm × 1.5-3 mm; valves glabrous or densely hirsute, torulose, usually with a prominent midvein; style (0.3-)0.7-3(-5.5) cm long; stigma slightly to distinctly 2-lobed and with decurrent lobes. Seeds oblong, 2-3(-3.5) × 1-2 mm; cotyledons conduplicate.  $2n = 24$ .

**Phenology.** Flowering March through June; fruiting May through July.

**Habitats.** Roadsides, gardens, forests, fields, thickets, valleys, hillsides; near sea level to 1300 m.

**Distribution.** Endemic to China and distributed in the provinces of Anhui, Gansu, Hebei, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Liaoning, Nei Mongol, Shaanxi, Shandong, Shanxi, Sichuan, and Zhejiang. Naturalized in Japan.

*Orychophragmus violaceus* is probably one of the most variable Chinese species of Brassicaceae. The variation is most dramatic in leaf morphology, especially in leaf size and margin, number of lateral lobes of cauline leaves, and size of auricles. Some authors (e.g., Tan et al., 1998) recognized three additional species, while others (e.g., Schulz, 1923)

recognized one species with five varieties. In some collections (e.g., *Henry 3411*) all the leaves are simple, whereas in others (e.g., the three type collections of *O. violaceus* var. *homaeophyllus* (Hance) O. E. Schulz, var. *hupehensis* (Pampanini) O. E. Schulz, *Cardamine potentillifolia*) all leaves have lateral, leaflet-like lobes. Other collections of the species fall between these two leaf morphs. The type of *O. taibaiensis* has uppermost leaves with minute auricles and no lateral lobes, and in *Wu 92–855* (MO) the lateral flowering branches have petiolate leaves without any auricles. In conclusion, these segregates of *O. violaceus* represent only a small fraction of the overall variability of the species, and we hope that the taxonomy of the species will not be confused any further by according formal recognition to additional variants.

*Orychophragmus violaceus* is also quite variable in flower size and fruit and style length. The shortest styles (ca. 3 mm) were observed in *Henry 1998* (GH, US) and the longest (ca. 55 mm) were in *Boufford et al. 26131* (MO). Such long styles are among the longest observed in the entire Brassicaceae, reaching to 3(5.5) cm (Al-Shehbaz, pers. obs.). The fruit length depends on the original number of ovules per locule and the number maturing into seeds. The shortest fruits (ca. 3 cm long) were observed in *Togashi s.n.* (A), the longest (ca. 13 cm) in *Deng 11005* (MO). Finally, the smallest flowers (ca. 1.2 cm long) were observed in the type of *Cardamine potentillifolia* and *Hangzhou Bot. Gard. 884* (MO). The largest (ca. 3.2 cm long) were found in *Farges 1330* (GH, P, US), *Wilson 220* (A, NY), and *Feng 51* (GH). The variation in these characters, however, is continuous between the extremes, and one often finds a wide range of forms within a single collection. Furthermore, the variation does not seem to follow any geographical lines. As a result of examining several hundred specimens, we prefer to recognize a highly variable species without any infraspecific taxa.

Forms with pubescent fruits, which occur sporadically throughout most of the species range, were recognized as *Orychophragmus violaceus* var. *lasiocarpus* Migo. However, these often occur mixed with glabrous forms in the same population, as evidenced from *Wang 96001* and *Wang 96068* (both at MO), which were collected in one area.

The measurements of every part of the plant given by Tan et al. (1998) for *Orychophragmus taibaiensis* and *O. diffusus* fall exactly within the general range of variation of typical plants of *O. violaceus*, and therefore the first two are reduced to synonymy of the last. These authors were mistaken in designating a neotype for their new combination

*O. hupehensis*, and it seems that they overlooked the fact that Pampanini (1910) cited under his *O. sonchifolius* var. *hupehensis* a single collection (*Silvestri 803*), which is the holotype that we had on loan from FI.

Hector Léveillé (see Launer, 1965) described a few variants of this species as *Arabis* L., *Cardamine* L., and *Raphanus* L., but failed in all cases to discover that he was dealing with one polymorphic species. Launer (1965) was correct in reducing Léveillé's *Arabis chanetii* to synonymy of *Orychophragmus violaceus*. He was also correct in excluding *Cardamine potentillifolia* from *Cardamine*, but he failed to associate the species with *O. violaceus*.

Because of its rich seed oil contents, attempts are made to domesticate *Orychophragmus violaceus* as a crop plant (Peng et al., 1995; Huang et al., 1999). The species is also grown as an ornamental plant and sometimes escapes from cultivation and becomes naturalized.

*Representative specimens examined* (the holdings of the species in the major Chinese, American, and European herbaria are enormous, and only the specimens representing some of the morphological extremes are cited). CHINA. **Anhui:** Shucheng Xian, *Deng 11005* (MO). **Henan:** Neixiang Xian, Baotianman Nature Reserve, Yinghu Guo, 33°22'N, 111°53'E, *Boufford, Liu, Ying, Zhang & Zhu 26131* (A, E, GH). **Hubei:** Nanto, *Wilson 220* (A, NY); without locality, *Henry 1998* (GH, US), *Henry 3411* (GH, US). **Jiangsu:** Nanjing Botanical Garden, *Wang 96001, 96068* (MO); Soochow, *Feng 51* (GH). **Shaanxi:** Taibaishan, *Wu 92–855* (MO). **Sichuan:** Tchen-keou-tin, *Farges 1130* (GH, P, US). **Zhejiang:** Yuhang Xiang, *Hangzhou Bot. Garden Team 884* (MO). JAPAN (naturalized): Tokyo, Sibguya-ku, Jingumae, 18 May 1971, *Togashi s.n.* (A).

**2. *Orychophragmus limprichtianus* (Pax) Al-Shehbaz & G. Yang, comb. nov.** Basionym: *Cardamine limprichtiana* Pax, Jahresber. Schles. Ges. Vaterl. Cutl. 89, Abt. 2: 27. 1911. TYPE: China. Zhejiang: Ningpo, 500 m, 18 Apr. 1911, *W. Limpricht 18* (holotype, WRSB).

*Cardamine hickinii* O. E. Schulz, Repert. Spec. Nov. Regni Veg. 17: 289. 1921. Syn. nov. TYPE: China. Zhejiang: Hangzhou, *H. J. Hickin s.n.* (holotype, K; fragments, B).

*Alliaria grandifolia* Z. X. An, Acta Phytotax. Sin. 23: 396. 1985. Syn. nov. TYPE: China. Zhejiang: Changhua, Yunxiwu, 2 June 1957, *He Xianyu 23442* (holotype, NAS, as JSBI).

Herbs annual or perennial, (12–)25–45(–80) cm tall. Stems erect, simple at base, often branched above, somewhat flexuous, glabrous or sparsely to densely pilose with trichomes to 1.5 mm long. Basal leaves not rosulate, simple or with 1 to 3 lateral lobes on each side; petiole (3–)5–15(–18) cm long,

flattened at base; blade or terminal leaf lobe cordate to broadly so, (2-)4-8(-10) × (1.5-)2.5-6(-8) cm, glabrous or sparsely to densely subappressed pilose abaxially, glabrous or sparsely pilose adaxially, sometimes ciliate, base cordate or rarely cordate-truncate, margin coarsely crenate with teeth ending in apiculae, apex acute to acuminate; lateral lobes sessile or petiolulate, 0.1-3 × 0.03-2 cm, sometimes absent. Uppermost stem leaves petiolate, much smaller to much larger than basal ones and up to 18 × 11 cm, base not auriculate, margin coarsely and irregularly dentate, rarely crenate, apex caudate to acuminate. Fruiting pedicels divaricate to recurved, glabrous or pilose, narrower than fruit, (0.5-)1-3(-3.5) cm long. Sepals oblong, ascending, 2-3.5 × 1-1.5 mm, base slightly saccate. Petals white, broadly obovate to narrowly obovate, (6-)7-9 × 3-6 mm, apex shallowly emarginate; claw obscurely differentiated, shorter than sepals. Filaments white, erect, 2.5-3.5 mm long; anthers oblong, 1-1.5 mm long, minutely apiculate. Ovules 20 to 35 per ovary. Fruits narrowly linear, stout, terete, (2-)3-6 cm × 1.5-2 mm; valves glabrous or sparsely pilose, strongly torulose, inconspicuously veined; style terete, 1-3 mm long; stigma 2-lobed, slightly decurrent. Seeds oblong, 2-3 × 0.8-1.2 mm; cotyledons conduplicate.

**Phenology.** Flowering March through May; fruiting April through June.

**Habitats.** Grassy areas along streams, moist slopes, roadsides, rocky slopes; 300-1200 m.

**Distribution.** Endemic to China in the provinces of Anhui and Zhejiang.

The type collections of *Cardamine limprichtiana* and *C. hickinii* have no mature fruits, and one suspects that Pax (1911) and Schulz (1921) assigned their species to *Cardamine* because the basal leaves have lateral, leaflet-like lobes, a feature quite common in *Cardamine* (Schulz, 1903), though it is also found in *Rorippa* and *Nasturtium* R. Brown (Al-Shehbaz & Price, 1998), *Yinshania* Y. C. Ma & Y. Z. Zhao (Al-Shehbaz et al., 1998), and *Orychophragmus* (Schulz, 1923). However, the two species do not belong to *Cardamine* because their replum is terete and the fruit valves are curved and strongly torulose, features that are found in *Orychophragmus*. *Cardamine* has flattened fruits with straight and non-torulose (smooth) valves. It also differs from *Orychophragmus* by having accumbent instead of conduplicate cotyledons.

Although the type of *Alliaria grandifolia* has mature seeds with conduplicate cotyledons, An (1985) did not mention anything about this cotyledonary position. Had he observed the cotyledons, it is very

likely that he would have assigned the species to *Orychophragmus* instead of *Alliaria*. *Alliaria* consists of two species, of which *A. petiolata* (Bieberstein) Cavara & Grande is a European and South-west Asian weed now naturalized worldwide, and *A. brachycarpa* Bieberstein is endemic to the Caucasus (Al-Shehbaz, 1988). *Alliaria* is readily separated from *Orychophragmus* by having longitudinally striate seeds with incumbent cotyledons instead of minutely reticulate seeds with conduplicate cotyledons. The two genera superficially resemble each other in having cordate, dentate or crenate basal leaves, petiolate cauline leaves, elongated fruits, and white flowers.

*Orychophragmus limprichtianus* is highly variable in the density of leaf indumentum, the size of uppermost leaves, and the number of lateral lobes on the basal leaves. Glabrous or very sparsely pilose forms with large uppermost leaves and rudimentary or no lateral lobes on basal leaves were described as *Alliaria grandifolia*, whereas moderately to densely pilose forms with smaller uppermost leaves and one to three pairs of lateral leaf lobes were recognized as *Cardamine limprichtiana* and *C. hickinii*. There are transitional forms between the two extremes in each of these three characters. In every other aspect of the plant, including flower size, margin of basal leaves, fruit and seed size and shape, length and orientation of fruiting pedicels, cotyledonary type, nature of the fruit valve (inconspicuously veined, torulose) and replum (terete), and flexuous stems, *A. grandifolia*, *C. limprichtiana*, and *C. hickinii* are indistinguishable. Therefore, we consider them as conspecific.

**Specimens examined.** CHINA. **Anhui:** San Yang, *Anhui Team 1665* (PE); Ji Xi, *Deng 90030* (NAS); Qi Yun Shan, *Shao Jiangzhang 82111* (PE); without locality, *Deng 115* (NAS); Xian Sanyan, *Dong 52* (MO). **Zhejiang:** Chun An, *Hong 841* (MO), *Hong 904* (MO); Hangzhou, *Hangzhou Botanical Garden Team 923* (MO), *Zhang Shaorao 2369* (PE), *He Xianyu 174* (IBSC); Ling Yinsze, *Merrill 2891* (K); Chang Hua, *Chiu 570* (MO), *Hangzhou Botanical Garden Team 433* (MO), *Anonymous 28598* (PE), *He Xianyu 22948* (IBSC, PE); Xian Ju, *Chang 7955* (MO); Tong Lu, *Hong 1976* (MO); Fei Lai Shan, *Chang 1869* (MO); without locality, *Barchet 36* (US); An Ji, *Deng 90143* (MO); His-Tienmu Shan, 23 Apr. 1936, *Migo s.n.* (NAS).

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